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EXPERIMENTAL ANALYSIS OF TWO-PHASE FLOW THROUGH CYLINDERICAL OBSTRUCTION IN VERTICAL PIPE

Isam Mejbel Abed and Rafel Hekmat Hameed
Department of Mechanical Engineering, College of Engineering, University of Babylon, Iraq

Laith Jaafer Habeeb
Training and Workshops Center, University of Technology, Baghdad, Iraq

ABSTRACT

The two-phase flow through vertical transparent pipe is investigated experimentally. The experimental rig designed to achieve the measurements of pressure drop for various combinations of phases, flow pattern regimes such as bubbly, slug and annular, with various range of water and air volumetric high speed camera . The air volumetric ranged from 8.3334 L/min to 25 l/min, while the water volumetric ranged from 5 l/min to 20 l/min and of 50 mm internal diameter along 1 m length. The measured of the pressure will be done using four pressure sensors along test pipe. The measured pressure values were used for different air volumetric and different water volumetric. It has been found that the measuring of pressure gradient through the distance of rig pipe are inversely changed with air volumetric. In addition, it has been analyzed the flow pattern through obstruction, it has showed one phase flow, bubbly and slug flow.

Key words: Two-Phase, air-water, flow, vertical pipe and cylindrical obstruction.

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1. INTRODUCTION

Gas and liquid phase two-phase flow in vertical pipe are encountered for various types of steam generators, heat exchangers and condensers. The pressure drop is importance parameter for two-phase flow to modeling flow pattern transition Ghajer [1]. Hassan Y.A [2] studied flow patterns experimentally by using a particle tracking flow visualization method (PTFV). This method provide an effective way .There are also several experimental ways of measuring pressure drop like manometers, subtraction of signals from two locally mounted pressure transducers and differential pressure transducer. Bui-Dinh [3] measuring the instantaneous bubble velocity through vertical pipe for two-phase flow regimes using digital image

processing algorithms. With same technique, the effect of design and scale of pipe studied by Alves de Oliveira et.al [4]. In addition, the effect of pipe diameter on bubbles size, whereas at small scale generated a large bubble, but no a large bubble discussed by Akira Ohnuki [5]. For inclined pipelines dominated slug flow regime and drift velocity was zero for the horizontal case, also it was increased with inclined pipe upwards from the horizontal position. Then decreased again toward the vertical position Bonnecaze et.al [6]. Some of researchers are studied flow regimes with or without obstructions effect, investigated effect of gaps of 0.3, 0.6 and 1.0 mm on vertical air-water two-phase flow using a camera that classified into slug, bubbly, churn turbulent and annular flow. Also, when the decrease of the channel gap, the transition from regime to another occurred at smaller flowrate gas and after increased the inclination angle, the void fraction appeared to be similar with a decreased trend. To collect and analysis data of slug, flow used electrical capacitance tomography and a non-intrusive advanced instrumentation. These parameters such as length of Taylor bubbles and liquid slug, void fraction in Taylor bubbles and liquid slug and pressure gradient in slug Olumayowa Timothy [7]. Also, increased with pipe inclined upwards from the horizontal position. Then decreased again toward the vertical position such that the maximum drift velocity occurred at an intermediate angle of inclination around 40^o to 60^o from the horizontal. The Pressure gradients directly affected on flow pattern. The void fraction correlation used to correlate experimental results for dispersed bubble and annular flow for predicting pressure drop and liquid holdup through inclined pipe. The transition lines in the flow regime map for air–water flow with surfactant of the 300-ppm concentration were mainly consistent with the experimental data obtained in clear air–water flow. Additive of surfactant to two-phase flow reduced the total pressure drop and decreased heat transfer, especially through the churn flow regime. Zhao and Bi [8] presented experimentally for the gas velocity, the pressure drop and void fraction of upward co-current air-water flow through vertical triangular channels. The various diameter of 0.866, 1.443 and 2.886 mm, various air superficial velocity ranging from (0.1 to 100) m/s and various water superficial velocity will be taken. The pressure drop through vertical miniature triangular channels could be well predicted by Lockhart and Martinelli correlation. Hagedorn and Brown [9] developed their correlation based on an experimental vertical well of 1500 ft length. The pressure drop during two-phase flow was studied in different pipes of 1 in, 1.25 in and 1.5 in nominal diameter. Air was used as the gas phase. The liquid phase was varied as water and crude oils. Liquid flow rates and GLR (gas liquid ratio) were also varied between the tests. During development of the correlation, they did not measure the liquid holdup. The correlation for liquid holdup is therefore not based on true measurements of liquid holdup.

The main purposes of the experimental work are firstly, to determine the pressure drop for different air and water superficial velocities through obstruction vertical pipe. Then, studying the pressure distribution effective and pressure drop through the vertical pipe. In addition, measuring the void effect of fluctuation for different air and water superficial velocities at different flow regimes was achieved.

2. EXPERIMENTAL SETUP

After building the system and installing all the measuring devices, the system was operated several once to ensure that there was no leak or any mistake in operating. In addition, there are a maintenance for system before any experiment. Seventeen experiments data are operating and fourteen experiments of them carried out for flow through cylindrical obstruction. All experimental conditions were repeated twice or three times. All experiments were studied turbulent flow and the pressure along the 1 m pipe and through cylindrical obstruction, where the influence of the process of water in water tank, and air storage tank. The main components of the rig are used in this work as shown in Figure (1). The schematic

diagram of the experimental work is shown in figure (2). It consists from pump: it is a device used to deliver the water from a tank to the test section through the water flow meter. The liquid feed line contained a valve to control the water volumetric, a check valve, and flow meter as shown in figure (1). The regulator valve used to control water flow rate. The pump used in this test to deliver the recirculation water from the accumulation tank to the water reservoir. It has maximum discharge of 0.036 m^3/min as Abdalellah [10].

The Water Flow Meter type (F.M.91425) was used. The flow enters the vertical tube and causes the float to move upward with a range of 0.002 to 0.030 m^3/min. The relation between the water flow meter discharge and that measured by stopwatch was linear. The Percentage error was about (±2%). By assuming the air as incompressible fluid and applying the Bernoulli's equation at two points after and before the orifice. The Percentage error was about (±0.4%). Table (1) gives the air properties.

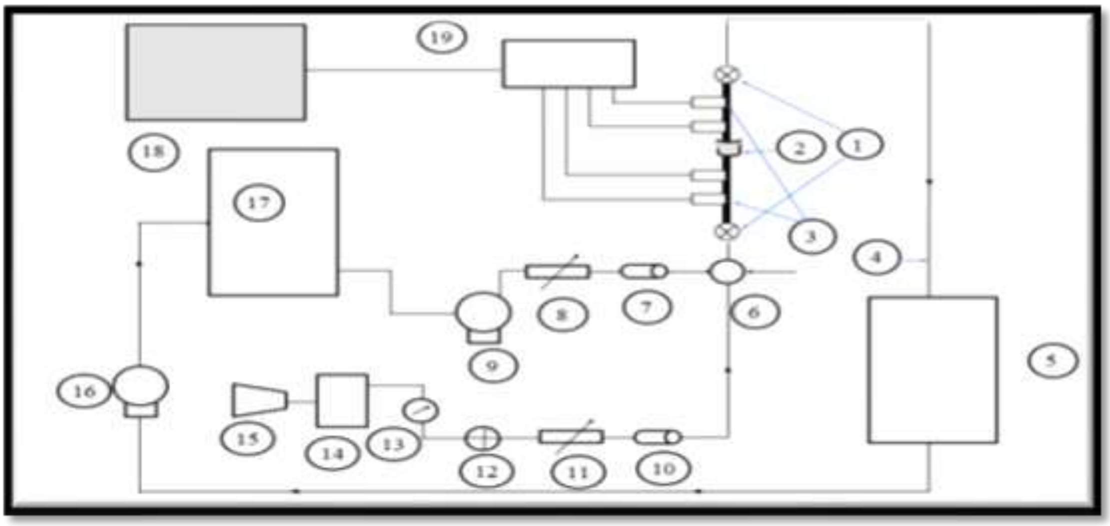

Figure 1 Schematic diagram of the experimental rig.

1. Water reservoir. 2. obstacle. 3. Pump. 4. Water flow regulator. 5. Water flow meter. 6. Water check valve. 7. Mixing chamber. 8. Air check valve. 9. Air flow meter. 10. Air flow regulator. 11.Pressure regulator. 12. Air

Table 1 Physical air properties at 25°C and 1.01325 bar[11].

Specific gravity	1.0
Density	1.185 kg/m3
Viscosity	1.82E-05 kg/m.s
Surface tension	7.28E-2 N/m

Air Reservoir is a container has a capacity of 1000 liter used to contain the air that coming from the compressor under a pressure range from 0 to 4 bar in order to deliver the air to the test section through the air flow meter. The water flow mixed with airflow at beginning in mixing chamber, and then the mixture flow through cylindrical obstruction inside pipe as shown in Figure 2, and Figure 3.

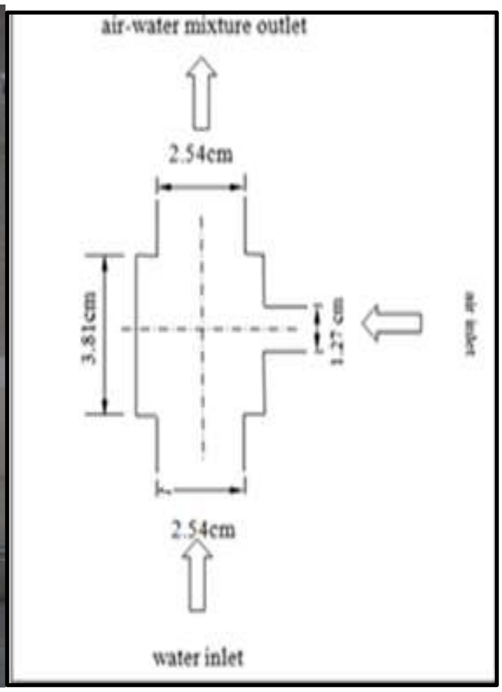

Figure 2: Test section of experimental tube. **Figure 3**: obstruction and mixing chamber.

A four pressure sensors with interface were used to measure the local pressure at four different locations along the test section. The sensor converted the pressure into an electrical signal. The data logger is used to make log of analog signals as shown in figure 4. This device is worked with the help DALI 08 software. Specification of the data logger given in table (2). The pressure sensors calibrated by using a U-tube manometer with mercury as liquid manometer. This process was performed by replacing sensor (1 and 5) by the manometer terminals. The average error between the calibrated and measured by sensors pressure drop did not exceed 4%.

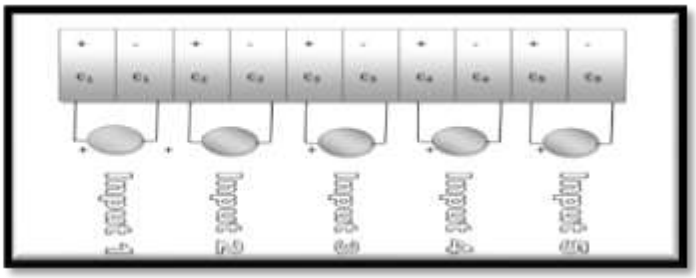

Figure 4: Connection diagram of the data logger.

Table 2 Data logger interface technical specification [12].

Supply voltage	5v AC ± 5%		
Power consumption	1 W		
Accuracy	± 2%		
Environmental temperature	Operation: -10 to 50°C	Storage -20 to 65°C	
Dimensions	Width: 72 mm	Height: 112 mm	Depth: 26 mm
Weight	87gr		

Firstly, step one should be provided water to tank and operating data logger to know the pressure in test section had been measured by the pressure sensors. The data logger collected the results for every second. Then the total time of the test was about 30 seconds. Secondly starting with water pumping by pump and flow meter was setting according matrix of experiment. At the same time of compressor was operating to provide air for system according matrix. The pressure sensors measured the pressures through test section and the voltage signals were transformed into digital signal, then the total time of the test was 30 second. The first sensor is located at a distance of 30 cm from test section edge. The second, third and fourth are fixed at a distance of 30 cm from each other as shown in figure 4.

The pressure drop was estimated reading first sensor as a reference. Then, the reading of the other sensors was subtracted from this reference reading. The pressure gradient was calculated by dividing the pressure drop that was determined above to the distance between the concerned sensors [13].

The difference percentages according the following equation:

$$\mathrm{DP} = \frac{expermantal\ value - theoritical\ or\ empirical\ value}{expermantal\ value} 100\% \qquad \ldots \qquad (1)$$

The pressure across the Perspex section was measured using pressure transduce. Pressure drop for all sections can be calculated by using pressure different equations as:

$$\Delta Pi = Pi+1-Pi \quad , \text{where } \ i=1, 2, 3,..... \qquad \ldots. \qquad (2)$$

The entrance length ($\boldsymbol{L_e}$) required for fully developed velocity profile turbulent flow according to Esam [11] is given as:

$$L_e \ = \ 4.4\, D\, (R_e)^{1/6} \qquad \ldots.. \qquad (3)$$

For present work and according to the pipe diameter, higher velocity is occur in the water, the entrance length ($L_e = 0.22\ m$) according to the above equation.

3. RESULTS AND DISCUSSIONS

3.1. Effect Pressure Fluctuation

To understand the effect of changing one phase volumetric on pressure fluctuation at constant another phase volumetric. It observed increasing fluctuating when increased one phase volumetric and constant another phase as figures (5) to (7). The instantaneous pressure reading of each sensor decreased with the increase of the vertical distance from fully develops region at the same experimental conditions and for different volumetric. Figures (5) to (7) show the pressure with time for different volumetric s. It is noted that the pressure fluctuate with time due to two-phase phenomena and obstruction. Figure (5) explain behavior flow for air volumetric 0 (L/min) and water volumetric 5 (L/min), it is observed the pressure values in sensor (1) is maximum with average (13.8) KPa, due to the mixture passes through the cylindrical obstruction. The pressure values in sensor (1),and sensor (2) are higher ,due to pressure decreased a long distance but the pressure gradient between the first two sensors and the last two sensors is very higher because of the mixture loosed his energy through cylindrical obstruction. In comparison figure (6) and (7), it observed a same behavior at increasing air and water volumetric because air and water passing accelerated flow and there increased pressure. The curve distortion values increased with increasing water and air volumetric and it's became maximum at maximum volumetric as [14,15].

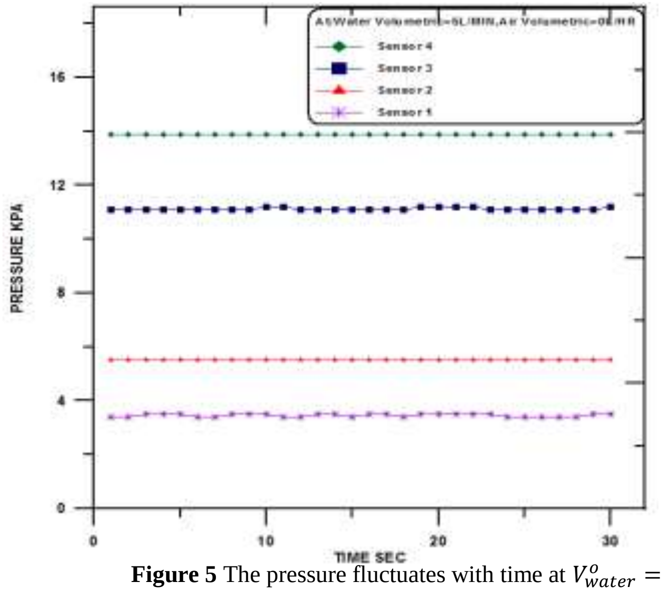

Figure 5 The pressure fluctuates with time at $V^{o}_{water} = 5\, L/min$ and $V^{o}_{air} = 0\, L/h$

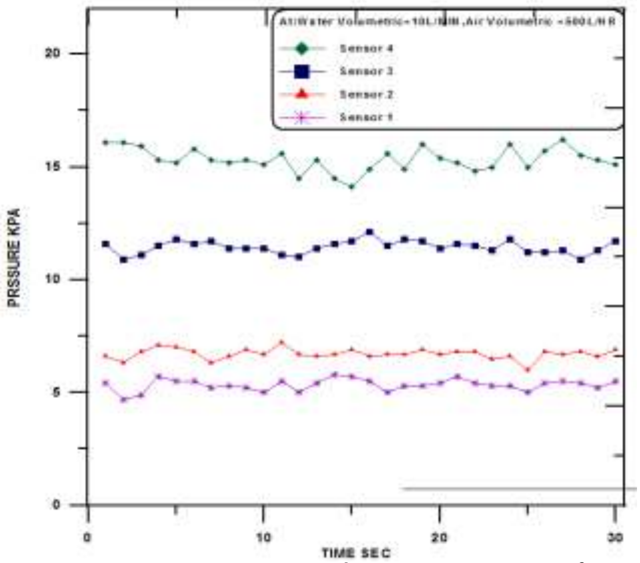

Figure 6: The pressure fluctuates with time at $V^{o}_{water} = 10\, L/min$ and $V^{o}_{air} = 500\, L/h$

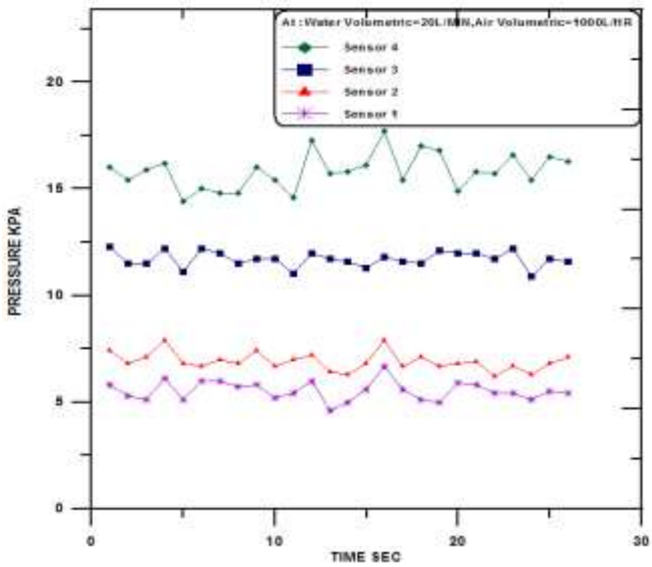

Figure 7: The pressure fluctuates with time at $V^{o}_{water} = 20\, L/min$ and $V^{o}_{air} = 1000\, L/h$

3.2. Effect of change Air Volumetric on pressure

The water volumetric with pressure at changed air volumetric from 0 to 1000 L/min with obstruction. The behavior of pressure curve decreased to downstream of flow passed through obstruction region. The gradient in curves represented the effect of (obstruction) cylinder founding in system. At figure (8), it observed when mixture entered test section the reading at sensor no.(1) and sensor no.(2) the different between reading is very small, but when comparison with reading sensor no. (3), then sensor no. (4), because of pressure drop at cylindrical obstruction.

In addition, it is observed when water volumetric increased from (5 to 20) L/min, the pressure along test section increased too with increased water volumetric. In comparison figure (9) and (10), (11), and (21), it observed a same behavior but increasing pressure values at increasing air volumetric due to air passing accelerated flow and their increased pressure.

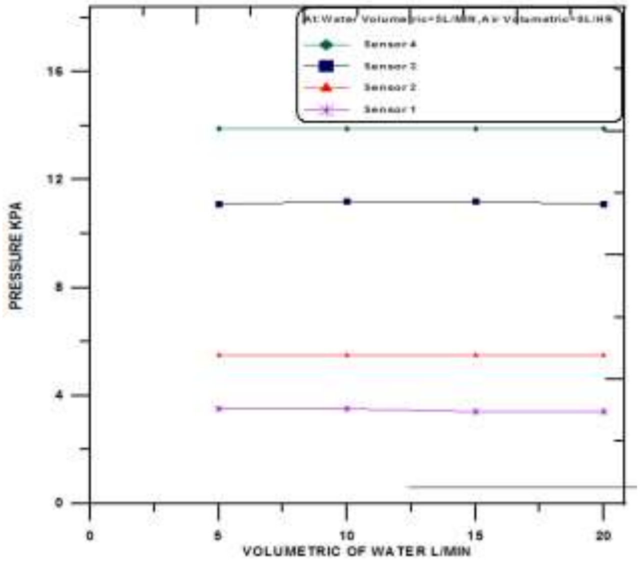

Figure 8: Pressure behavior at air volumetric 0

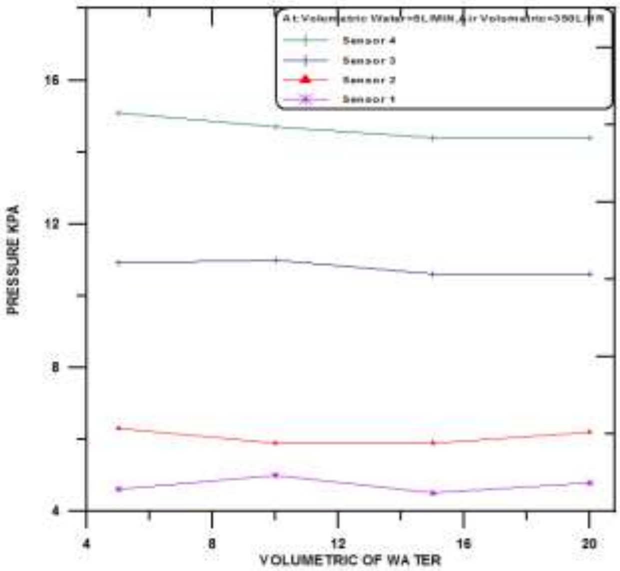

Figure 9: Pressure behavior at air volumetric 5

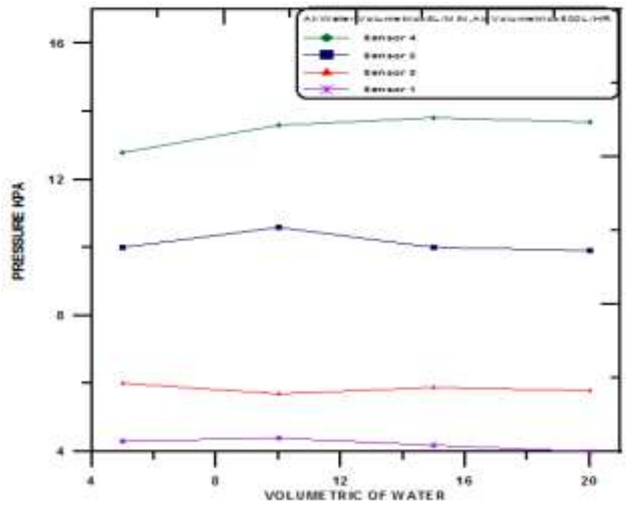

Figure 10: Pressure behavior at air volumetric 500 L/HR

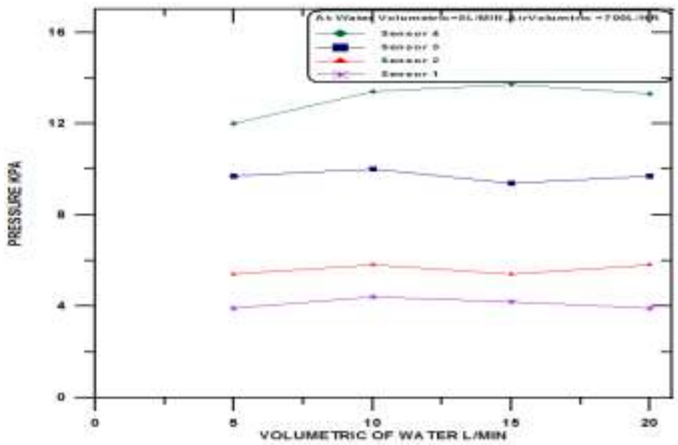

Figure 11: Pressure behavior at air volumetric 700 L/HR

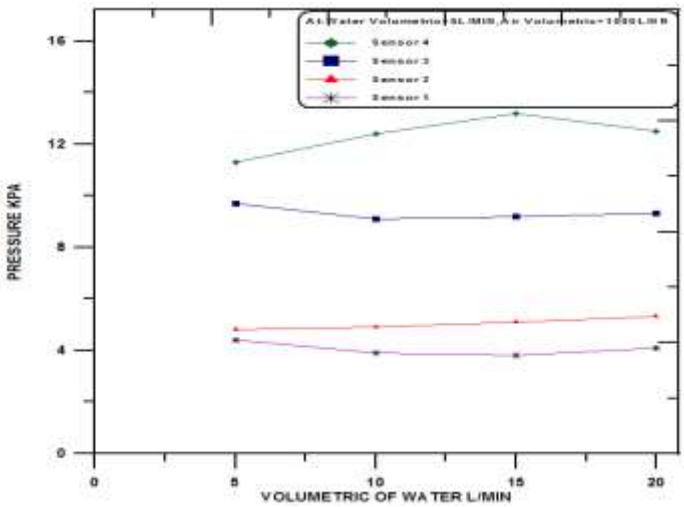

Figure 12: Pressure behavior at air volumetric 1000 L/HR

3.3. Effect of change water volumetric on pressure at constant air volumetric

The water volumetric with pressure at constant air volumetric 500 (L/hr.) with obstruction. Figure (13) the behavior of curve increased with increasing water volumetric at constant air volumetric .The reasons that increasing air volumetric increasing pressure. When increasing water volumetric in figure (13), (14), (15), and (16), and observed keeping the behavior.

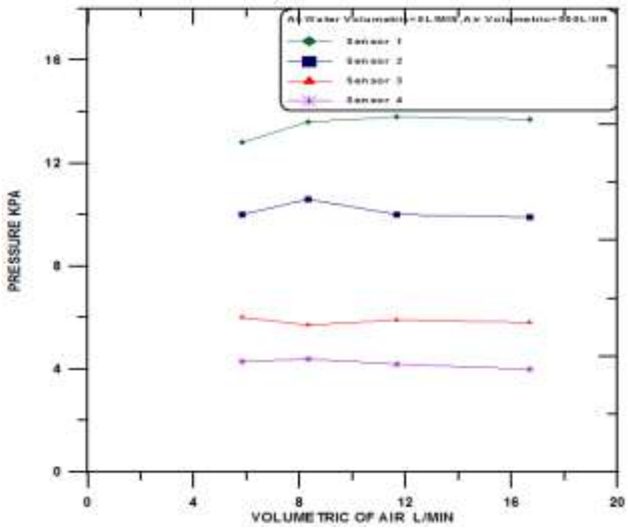

Figure 13: Pressure behavior at water volumetric 5 L/min

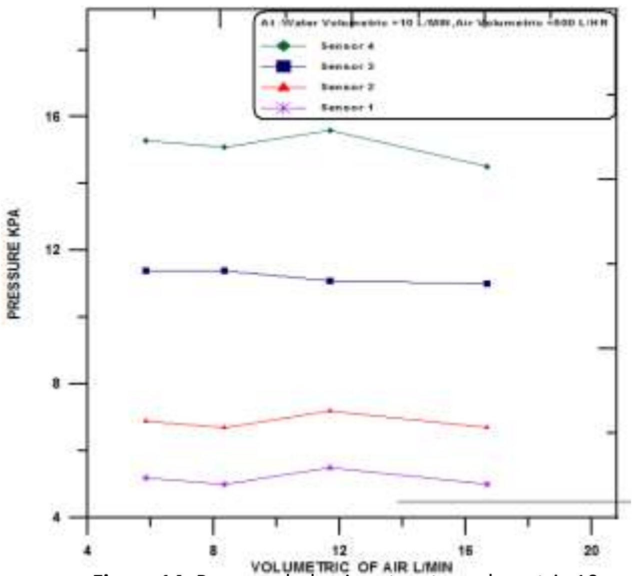

Figure 14: Pressure behavior at water volumetric 10 L/min

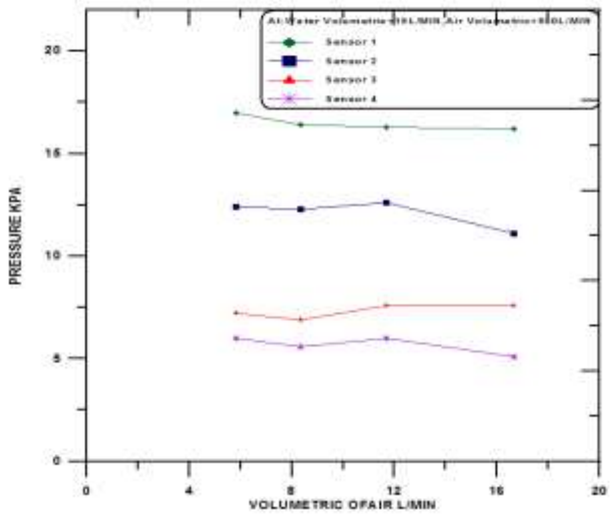

Figure 15: Pressure behavior at water volumetric 15 L/min

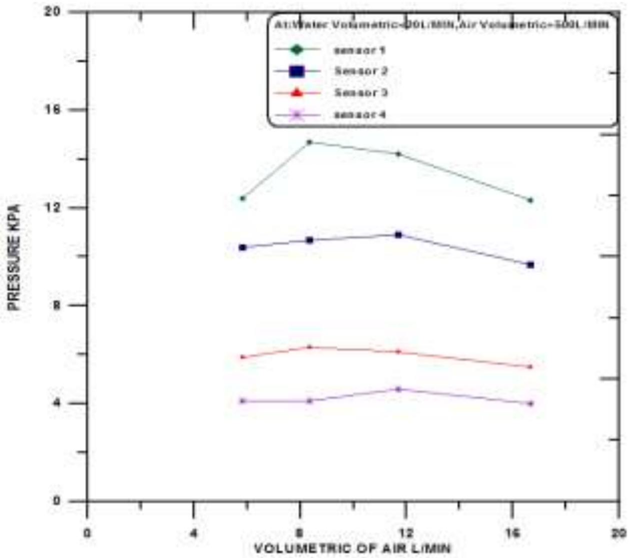

Figure 16: Pressure behavior at water volumetric 20 L/min

3.4. Effect of Distance on pressure at change air and water volumetric.

The pressure will be decreased along downstream flow in curve behavior for different volumetric of air and water. Figure (17) represent the pressure for four sensors at places 0.1, 0.4, 0.6 and 1 m from the entrance of tube, its observed in first and second points maximum values in comparison with the last points because of the obstruction. In addition, it is observed sharply slop in (0.4 and 0.6) mm because of finding obstruction. Figure (18) and (19), it is observed a same behavior with previous figure but it increased pressure values because increasing in air and water volumetric in flow [16].

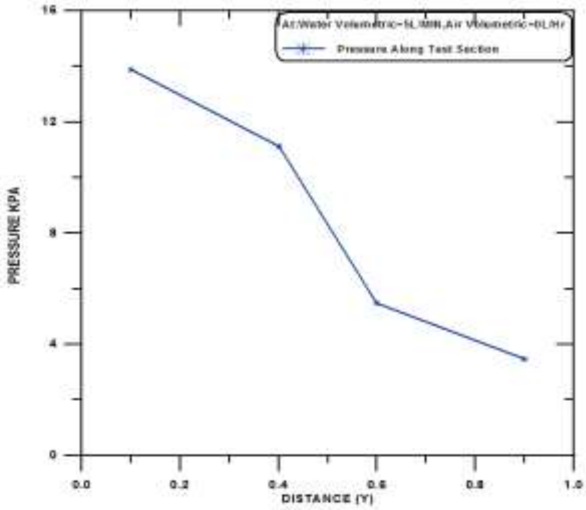

Figure 17: Pressure behavior with sensors places at
$V^o_{water} = 5\,L/min$ and $V^o_{air} = 0\,L/h$

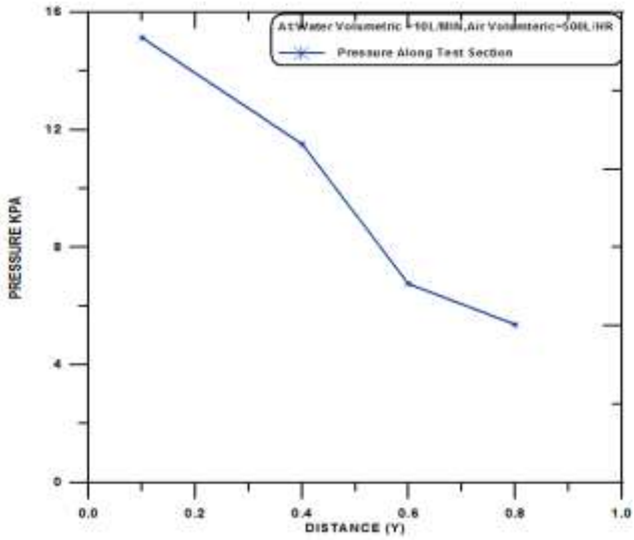

Figure 18: Pressure behavior with sensors places at
$V^o_{water} = 10\,L/min$ and $V^o_{air} = 500\,L/h$

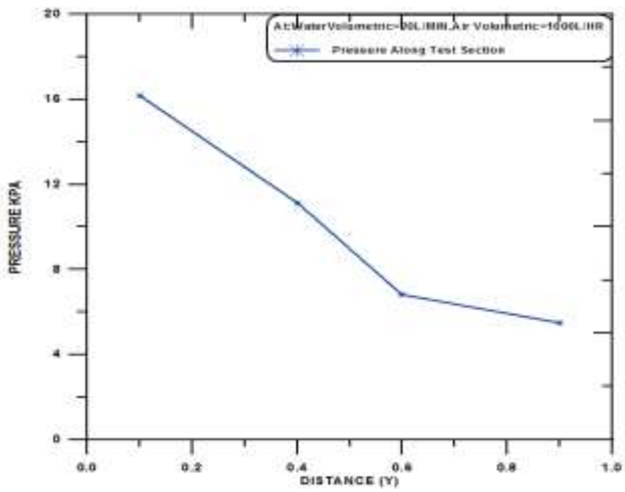

Figure 19: Pressure behavior with sensors places at
$V^o_{water} = 20\,L/min$ and $V^o_{air} = 1000\,L/h$

4. IMAGE ANALYSIS

To understand the flow pattern through obstruction region, it should analysis pictures of flow. Figure (20) represented the flow of one phase through obstruction, it observed appearance increasing eddies when increased water volumetric. Figure (21) represented the flow for two-phase and appeared bubble of air but its quantity decreased when increased water volumetric .This type of flow pattern called "bubbly flow". Figure (22) represented the flow for two-phase and increased bubble of air but its quantity decreased when increased water volumetric .This type of flow pattern called "slug flow”. Figure (23) and (24) represented the flow for two-phase and increased bubble because of air volumetric increasing but its quantity decreased when increased water volumetric [19].

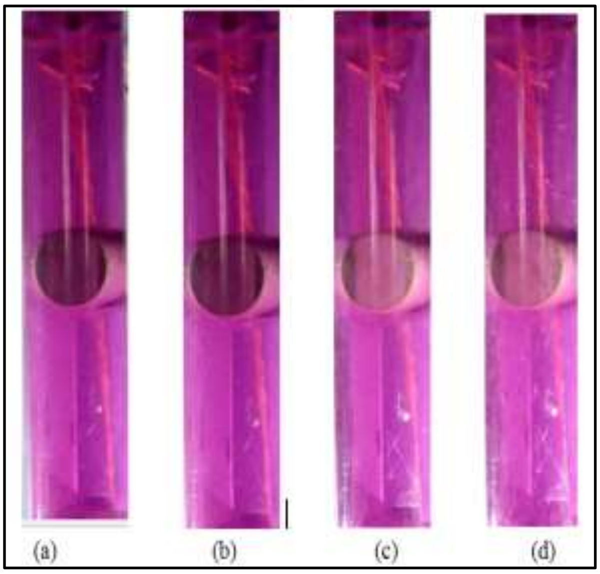

Figure 20: flow pattern of air at 0 L/h and water at
(a) 5 L/min. (b) 10 L/min. (c) 15 L/min. (d) 20 L/min.

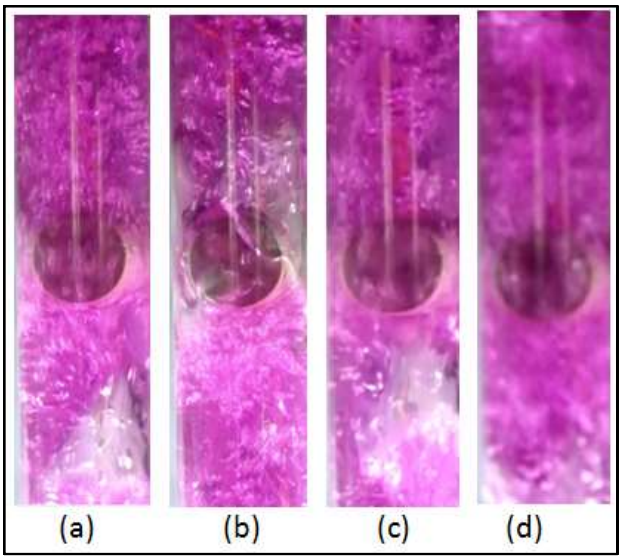

Figure 21: flow pattern of air at 350 L/h and water at
(a) 5 L/min. (b) 10 L/min. (c) 15 L/min. (d) 20 L/min.

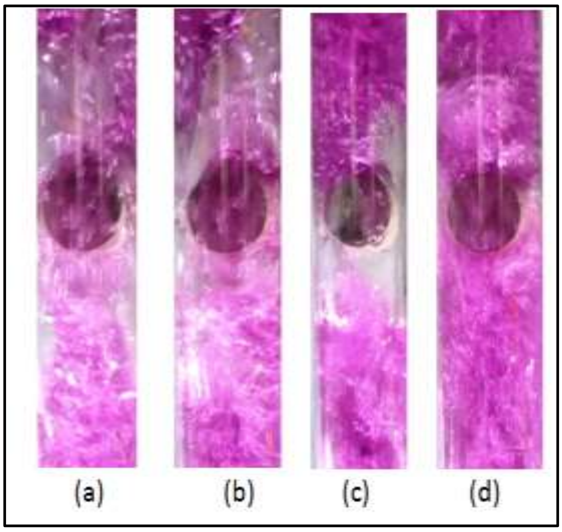

Figure 22: flow pattern of air at 500 L/h and water at
(a. 5 L/min. (b) 10 L/min. (c) 15 L/min. (d) 20 L/min.

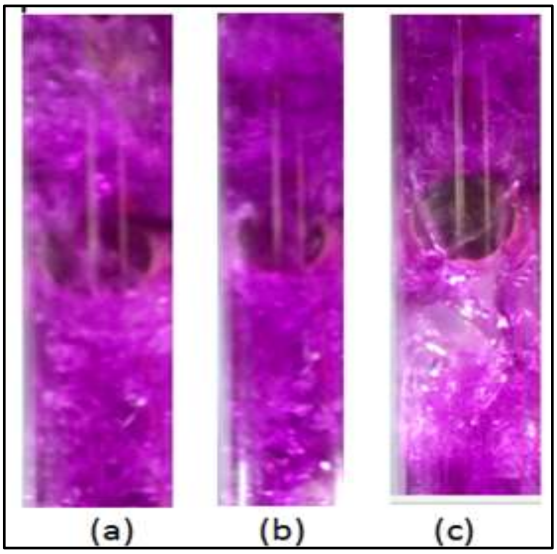

Figure 23: flow pattern of air at 700 L/h and water at
(a) 5 L/min. (b) 10 L/min. (c) 15 L/min.

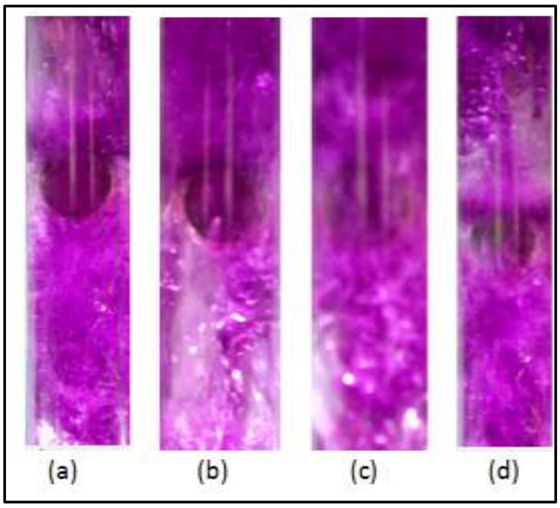

Figure 24: flow pattern of air at 1000 L/h and water at
(a) 5 L/min. (b) 10 L/min. (c) 15 L/min. (d) 20 L/min.

5. CONCLUSION

The experiments were conducted on a two-phase flow to find the effect of volumetric of air, pressure drop, and flow pattern through obstruction. The operational principle of the two-phase through obstruction requires only measurements of pressure differences and the knowledge of the gas-liquid properties. It observed increased fluctuating when increased two phases volumetric. The pressure along test section decreased when the water volumetric increased, but it's observed a higher gradient in pressure between the first two and the last two sensors due to the obstruction. In addition, its observed curve behavior increased with increasing air volumetric at constant water flow and pressure values decreased a long distance with a sharply slop in obstruction region . Finally, the phase distribution will change from bubbly to slug flow after increased volumetric airflow rate and the obstruction will destroy the flow pattern.

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